

OGO-5 SPECTROMETER

68-014A-18A

This data set consists of 14 tapes. These tapes are 300 BPI, 7-track, binary with anywhere from 9 to 14 files per tape. Note: each tape is ended with a triple EOF.

The tapes contain header records in BCD format. The data records consist of 36 bit floating point words. The format for the data records is:

<u>WORD</u>	<u>DESCRIPTION</u>
1	JULIAN DAY
2	UNIVERSAL TIME
3	ION CONCENTRATION
4	GEODETTIC LATITUDE
5	GEODETTIC LONGITUDE
6	ALTITUDE
7	L
8	DISTANCE
9	LOCAL TIME
10	MAGNETIC LATITUDE
11	EGRESS LATITUDE
12	INGRESS LATITUDE

The time spans for the tapes are:

<u>D#</u>	<u>C#</u>	<u>FILES</u>	<u>TIME SPAN</u>
D-06071	C-04591	12	3/07/68 - 3/30/68
D-06072	C-05345	11	4/01/68 - 4/23/68
D-06073	C-04592	9	6/13/68 - 6/29/68
D-06074	C-04593	14	7/01/68 - 7/30/68
D-06075	C-04594	14	8/02/68 - 8/31/68

<u>D#</u>	<u>C#</u>	<u>FILES</u>	<u>TIME SPAN</u>
D-06076	C-04595	13	9/02/68 - 9/28/68
D-06077	C-04596	14	10/01/68 - 10/30/68
D-06078	C-04597	14	11/01/68 - 11/30/68
D-06079	C-04598	14	12/02/68 - 12/31/68
D-06080	C-04599	13	1/02/69 - 1/31/69
D-06081	C-04600	12	2/03/69 - 2/26/69
D-11544	C-08905	14	2/28/69 - 3/29/69
D-11545	C-08906	13	4/01/69 - 4/30/69
D-11546	C-08907	14	5/02/69 - 5/31/69

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5 May 1971

National Space Science Data Center
Code 601
Goddard Space Flight Center
Greenbelt, Maryland 20771

Gentlemen:

Accompanying this letter is a shipment of processed magnetic data tapes from the experiment E-18, A Light Ion Mass Spectrometer, for OGO-5.

The data contained on these magnetic tapes are in final analyzed form for the data acquired for the first year of instrument operation. This shipment is in accordance with "A Plan for Submission of Data from Experiment E-18 on OGO-V," Contract No. NAS 5-9092, and forms a portion of the data to be submitted to the National Space Science Data Center as per contract specifications. Additional data will be submitted in the form of charts, graphs, tables, etc., which formed the basis of published results. These additional data will accompany or appropriately be included in the final report to be subsequently submitted.

The format of the data contained on the magnetic tapes included herein is as follows: Each magnetic tape is written with 800 bits per inch, odd parity and binary; each word is a 36 bit word floating point, the left nine bits forming the characteristic; the first record is an indicative record written in BCD format, containing the number of files on tape, the month of year of the data acquisition and the beginning and ending orbit numbers, and address of principal investigators; the files are in ordered records of Oxygen (oxy), Helium (Hel) and Hydrogen (Hyd); each record consists of a 12 by X matrix with $X \leq 500$, the matrix elements in order are (1) day 2) universal time 3) ion concentration 4) geodetic latitude 5) geodetic longitude 6) altitude 7) L 8) distance 9) local time 10) magnetic latitude 11) egress latitude 12) ingress latitude. At the end of tape are placed 3 end of file marks.

A complete description of all computer programs developed for data analysis will be included within the final report.

Respectfully,

Kent K. Harris

Dr. Kent K. Harris
OGO-5 Experimentor
Space Sciences Laboratory

Enclosure

LOCKHEED MISSILES & SPACE COMPANY • A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

Chapter 3

DATA ANALYSIS

3.1 DATA

The data from the LIMS is received from Goddard Space Flight Center (GSFC) in the form of magnetic tapes. The data have been preliminarily processed to be compatible with the Univac 1108 computing facility of Lockheed Missiles and Space Company. The processed tapes have been remarkably free from errors. Only on rare occasions has it been necessary to return a magnetic tape to GSFC to be reprocessed because it contained noisy or otherwise unmanageable data. Along with the basic data tapes magnetic tapes containing a complete set of orbit-altitude information were also supplied by GSFC. The analysis of the data from the LIMS required utilizing both the data tape and the orbit-attitude data as described in the following sub-section.

3.2 THE APPROACH TO ANALYSIS

The primary purpose of the LIMS was to obtain data on the cold ion distribution within the plasmasphere and plasmatrough. Although many others functions could be performed by the LIMS in the OGO-5 mission (e.g. measure the low energy component of the solar wind, measure the thermal H^+ ion distribution in the magnetosheath, determine bow shock, magnetosheath and magnetopause boundaries, etc.), these were relegated to secondary importance and thereby given only casual attention. The majority of the effort in

reducing and analyzing the LIMS data was confined to the region within approximately 12 earth radii (R_e).

As has been described earlier in this report the LIMS is an instrument designed to look in the direction of the spacecraft velocity vector. In the region where the spacecraft velocity is large compared to the most probable ion thermal velocity, α , the ions are "scooped in" by the instrument. The measured ion current is then simply related to the ambient cold plasma density by

$$I_i^+ = N_i^+ AV \cos \theta F_i \quad (3-1)$$

where: I_i^+ = ion current of species i measured by the electrometer of the LIMS.

N_i^+ = the ambient density of species i

A = the area of the entrance aperture of the LIMS

V = velocity of the spacecraft,

θ = angle between the velocity vector and the normal to the entrance aperture plane.

F = the product of the transmission of the spectrometer and gain of the electron multiplier for species i .

The above expression (Eq. 3-1) is accurate to better than 3% even when the most probable ion velocity is equal to the spacecraft velocity. As the most probable ion velocity increases relative to the spacecraft velocity the relation becomes less and less valid. This relation is valid to within a factor of two even when α is as much as a factor of 5 greater than V .

The most probable ion velocity α depends upon the temperature and mass of the ion:

$$\alpha = (2FT/M)^{1/2} \quad (3-2)$$

therefore α is uncertain to the degree that the ion temperature is unknown.

For the region within the plasmasphere (i.e. when the spacecraft is within from 6 to 8 Re) the ion temperature is probably somewhat less than 10,000°C. However, at this temperature and assuming the OGO-5 vehicle velocity corresponding to approximately 5 Re, the error in utilizing Eq. 3-1 for O⁺ ions, He⁺ ions and H⁺ ions is 0%, 9% and 40% respectively. Thus for analysis of the LIMS data, keeping in mind the uncertainty of the ion temperatures, Equation 3-1 will be utilized to obtain ambient densities of the cold plasma.

The ion densities were calculated from Equation 3-1 with angles θ and velocities V determined from the orbit-attitude tape. The concentration data thus calculated were merged with several of the important geophysical parameters from the orbit-attitude tape and a final data magnetic tape was generated. The data for the entire first year of operation were analyzed and final data tapes constructed. The format of the data contained on the magnetic tapes is as follows: Each magnetic tape is written with 800 bits per inch, odd parity and binary; each word is a 36 bit word floating point, the left nine bits forming the characteristic; the first record is an indicative record written in B. C. D. format, containing the number of files on tape, the month of the year of data acquisition, and the beginning and ending orbit numbers, and address of principal investigators; the files are

in ordered records of oxygen (OXY), helium (HeL) and hydrogen (Hyd); each record consists of a 12 by x matrix with $x \leq 500$, the matrix elements in order are 1) day, 2) universal time, 3) ion concentration 4) geodetic latitude, 5) geodetic longitude, 6) altitude, 7) L, 8) distance, 9) local time, 10) magnetic latitude, 11) egress latitude, 12) ingress latitude.

At the end of tape are placed 3 end of file marks. Each final data tape contains data for one specific month of instrument operation.

In the region of the magnetosheath the thermal distribution of H^+ ions is readily measured between 0-600 electron volts. The LIMS covers this region for H^+ ions very well but is displayed only when the larger data rates from the telemetry system (8 and 64 kilobits) are being used. Consequently several 0 to 600 eV thermal distributions of H^+ ions have been acquired and analyzed. These analyses are confined roughly within the orbital range from 8 Re outbound to apogee, and from apogee inbound to 8 Re. From these data the crossing of the boundaries of the various magnetospheric regions were readily discernable. The crossing of the bow shock was particularly dramatic. Signal levels from the LIMS dropped as much as 3 orders of magnitude when passing from the magnetosheath region through the bow shock and out into the solar wind.

The proton energy spectrum is determined for the energy range 0-600 volts in the period of time of the basic sweep cycle of the LIMS, i.e. approx. 4 sec.

The LIMS was designed to focus cold (essentially 0 volt) protons (H^+) through the instrument when the accelerating voltage was -600 volts. A proton with 10 volts energy and properly directed into the entrance aperture of the instrument will focus at -590 volts. In like manner, a 600 volt proton directed with 0° angle of attack into the instrument will focus through

the instrument when the accelerating voltage is 0 volts. In this latter case, the proton signal will appear at the beginning of what is called the "oxygen" state of the instrument. It is then clear that the energy of an entering ion is given by

$$E_p = 600 + V_s \quad (3-3)$$

where E_p = proton energy in volts
 V_s = sweep potential in volts.

Rather than detect a peak as in the case of the normal mass spectroscopy mode, the signal is then spread out over the full range of the sweep due to the energy distribution of the protons that are being focused thru the instrument. The detailed shape of the sweep of the accelerating potential as a function of time is known. With this information the signal out of the electrometer is converted from a time dependent function to an accelerating potential dependent function. This, in turn, is then converted to the proton energy distribution. The display of this data will then be in the form of the proton energy distribution for specific universal times. These times being the start of each sweep cycle.

3.3 DATA ANALYSIS PROBLEMS

Many circumstances have occurred which have complicated the analysis of the data. Telemetry points on equipment group #2 were shared with experiment E-26 under a pre-arranged schedule. The data from the spacecraft when being transmitted on equipment group #2 therefore frequently came in piecemeal form. This substantially complicated the data analysis procedures; but even more important, it frequently created discontinuities in the LIMS

data, sometimes at rather critical points. The problem of piecemeal acquisition of data was compounded further by the failure of wideband transmitter A. The data transmittal procedures utilized after this failure returned the data for relatively short periods of operation.

The electron multiplier in the LIMS, as has been previously described, operated serially and cyclic in two modes, a high gain mode and a low gain mode. It was discovered that calibration of the high gain mode had changed relative to the low gain mode. It was suspected that this situation did arise from a small deposit of vacuum pump oil on the multiplier plates during the extensive pre-launch testing of the instrument. The high gain calibration was then corrected by normalizing to the low gain calibration in their region of overlap. This circumstance continued from initial turn on until about March 20, 1968, when the gain of the high gain mode shifted back to nearly the value of laboratory calibration. This phenomenon was interpreted as an expurgation of the surface of the multiplier plates by the removal of the vacuum pump oil. These two operational characteristics of the LIMS were appropriately compensated for in the computer programs that were developed to analyze the data. After these initial problems with the electron multiplier, no further abrupt changes in multiplier operation were detected except perhaps for the ultimate failure of the multiplier power supply. This can not be properly determined until the second year of data is analyzed. The inflight calibration system of the LIMS showed that a slight multiplier decay transpired throughout much of the flight. This decay was carefully followed and the final data were corrected to reflect the slightly changing gain of the multiplier.

One further difficulty in data analysis occurred when the sweep monitor circuit failed. As described above, the entire mode of operation

of the LIMS assumed a new pattern. This of course required another programming change to properly extract the data.

3.4 COMPUTER PROGRAMS

The computer programs that have been developed to analyze the LIMS data fall basically into two categories. One category encompasses the primary program of data analysis, i.e., the cold plasma in the region of the plasmasphere and plasma trough. The other category is that of the proton energy distribution in the 0-600 eV range. In the first category 3 similar computer programs were developed to reduce the data to an analyzable form. The three programs correspond to the 3 modes of instrument operation described above. The first program, OGO-E-1, is utilized for the data prior to 20 March 1968. This program compensates for the shift in calibration of the high gain mode of the electron multiplier. The second program, OGO-E-2, is utilized for data after 20 March 1968 to 22 April 1968. During this period the multiplier calibration was re-established near the laboratory level. After 22 April 1968 the third computer program OGO-E-3 was used. This program incorporated the change in the instrument logic caused by the failure of the sweep monitor circuit. In addition to these 3 basic programs, other computer programs were developed to display the data in convenient forms. The most frequently used program was that program which plotted the ion concentrations as a function of the geomagnetic parameter, L. The listings of this plot program, the ion concentration programs OGO-E-1 and OGO-E-3 and the proton energy distribution from 0-600 eV are given in the Appendices.

These magnetic tapes have been received by the National Space
Science Data Center.

OGO-5, Experiment E-18

Tape #

OGO-5	March 68
OGO-5	April 68
OGO-5	June 68
OGO-5	July 68
OGO-5	August 68
OGO-5	September 68
OGO-5	October 68
OGO-5	November 68
OGO-5	December 68
OGO-5	January 69
OGO-5	February 69

Signed

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